The Technology of Perch Aquaculture

Richard W. Soderberg and John T. Quigley

THE COVER shows a popular type of plastic biological filter media often used in closed aquaculture systems. This media type is referred to in this publication as "plastic rings."

Photo by Peyton Smith

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by

Richard W. Soderberg

&

John T. Quigley

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Introduction

This lecture was presented as a program on the Wisconsin Educational Telephone Network (ETN) on October 25, 1977. ETN is located in every county of the state at designated listening stations. The registered listening audience for this program numbered 171 people from all over Wisconsin.

The purpose of the program was to present the water reuse aquaculture system being developed at the University of Wisconsin with special emphasis on energy requirements and possible cost saving alternatives. Following is the text of the program and the question and answer session that followed.

Wisconsin State Journal

The purpose of water reuse in aquaculture is to conserve heat energy while increasing fish production over what could be obtained through the use of a given volume of water in a single pass system. Wastewater from intensive husbandry is not suitable for perch culture and must be treated to partially restore its original quality before reuse.

Treatment is generally accomplished in three steps in the systems employed at the University of Wisconsin. After passing through the fish rearing tank, the first treatment step is primary clarification where the bulk of the suspended solids is settled out. Further clarification takes place as the water is forced through a pressure sand filter. Finally, the water is passed through a biological filter to convert ammonia, a toxic product of fish metabolism, to nitrate, a less toxic form of nitrogen.

Primary Clarification

Primary clarification normally takes place in a settling tank where sedimentation occurs by gravity. See figure 1.

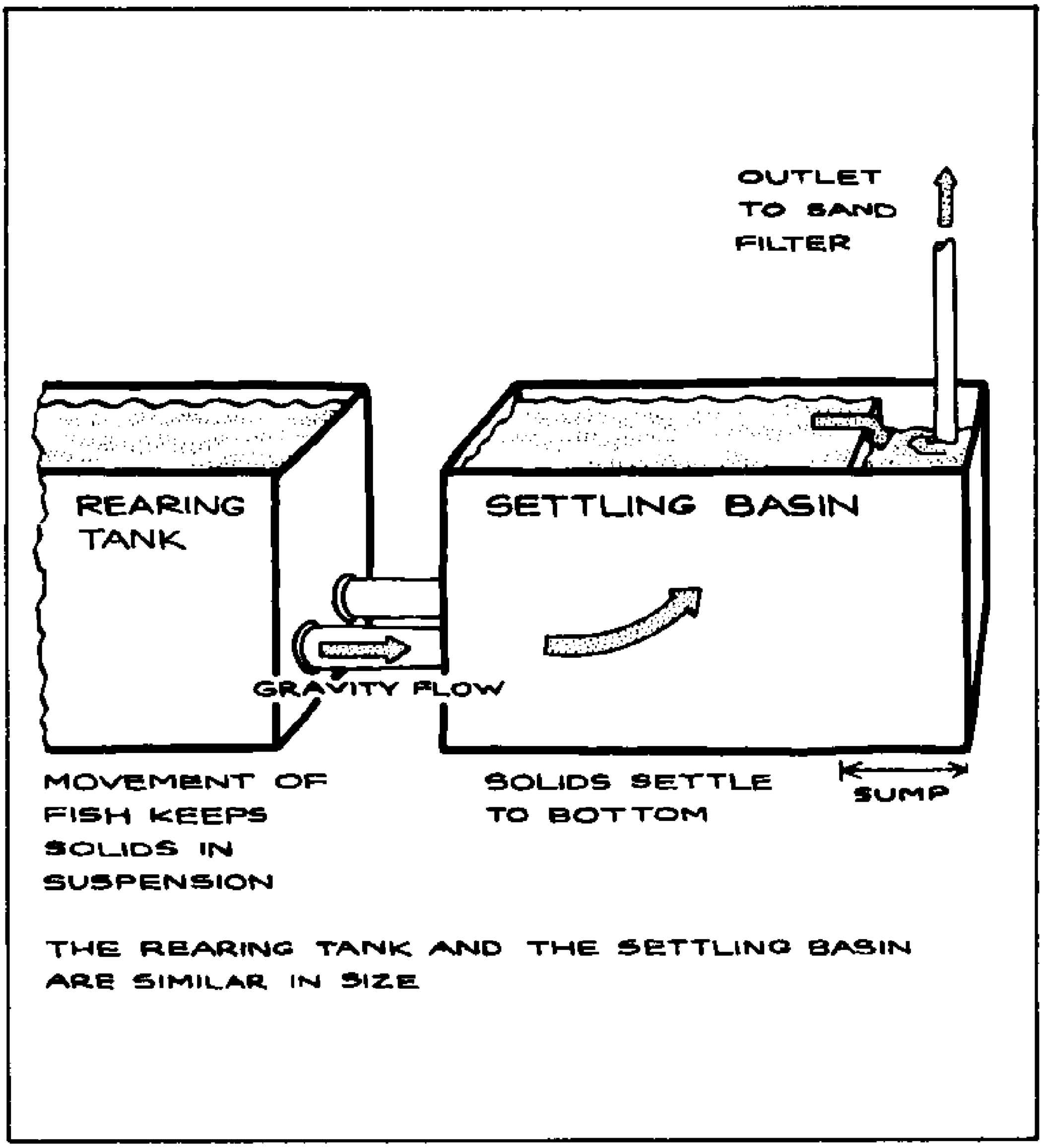


FIGURE 1 SETTLING BASIN

The nature of fish waste makes primary clarification with a settling tank difficult. Because the density of the suspended matter is so close to that of water, the settling tank must be nearly as large as the fish rearing tank in order for a substantial amount of the suspended material to settle out. This wastes floor space and takes half of the tempered water out of fish production.

An alternate method of removing suspended matter from the production water is through the use of a tube settler. See figure 2.

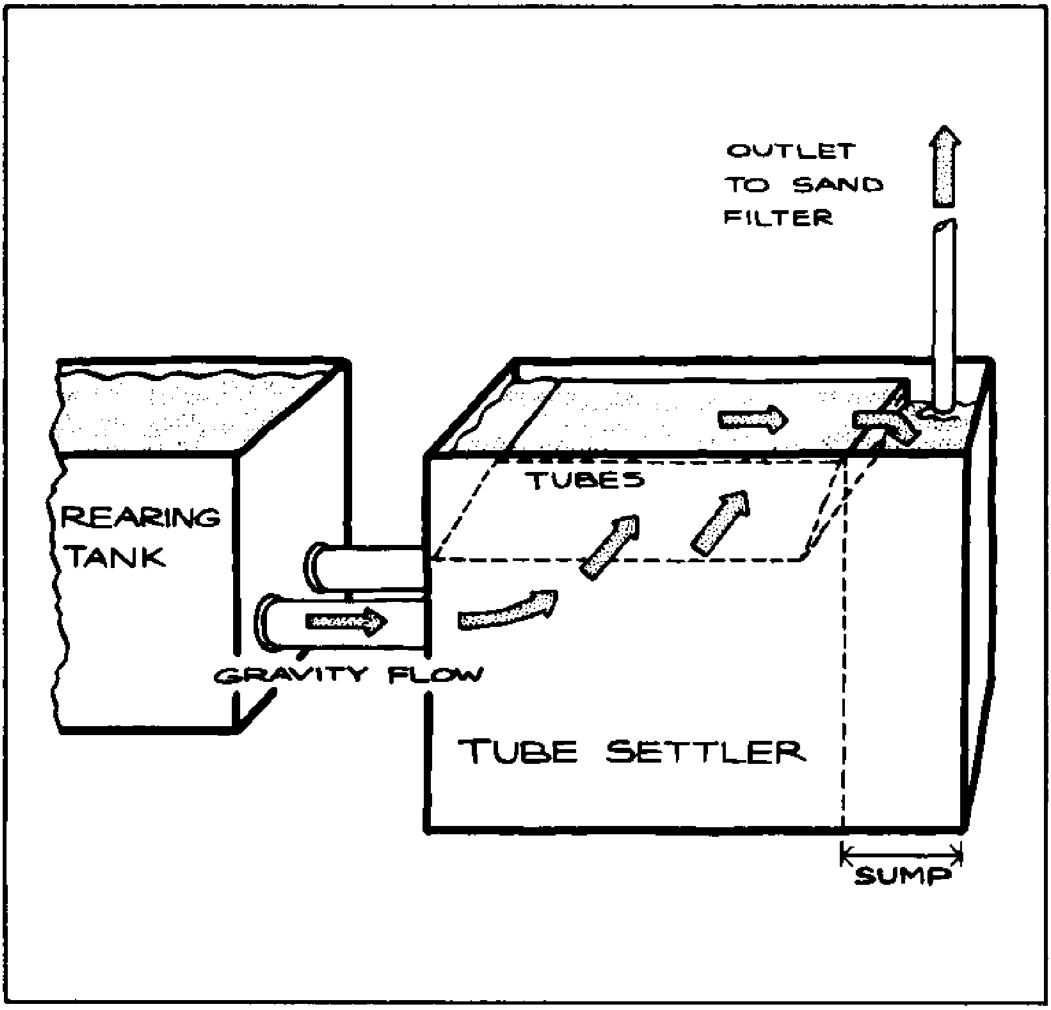


FIGURE 2 TUBE SETTLER

In the tube settler, the effluent from the fish growing tank enters the bottom of the unit and flows upward through diagonal tubes. The solid material settles out of the water, collects on the inner surfaces of the tubes and slides down to the bottom of the tube settler unit. The tube settler may require only about one-third of the floor space that a plain settling tank does, contributing significantly to space efficiency.

Tube settlers are used for primary clarification at the new Aquaculture Demonstration Unit where they will be fully evaluated for service in water reuse aquaculture.

Filtration

After primary clarification, the wastewater should be further cleansed of suspended solids by filtration. This is accomplished in the University of Wisconsin systems with swimming pool sand filters. See figure 3.

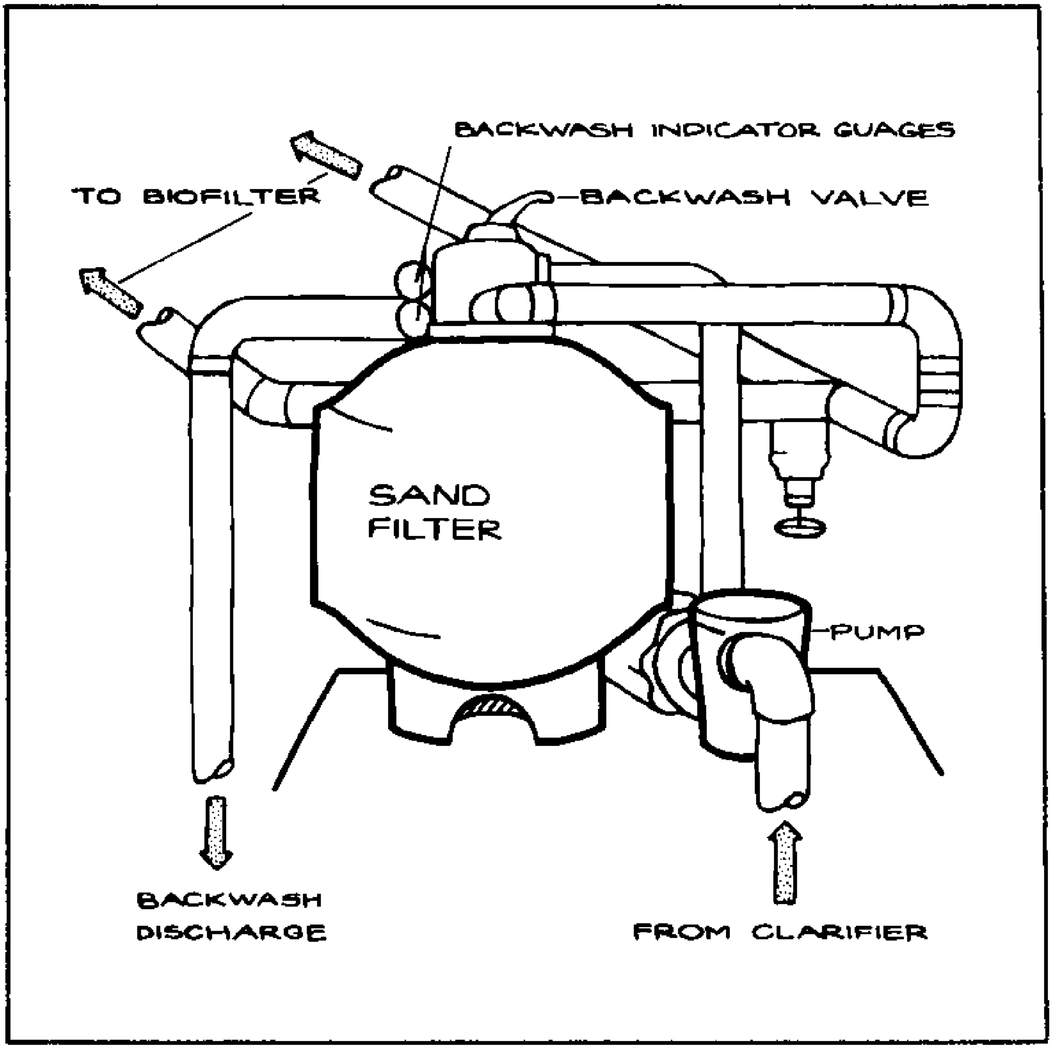


FIGURE 3 SAND FILTER

These units force the water through a column of sand and gravel, removing most of the remaining organic matter and lifting the water to the biological filter. When flow through the sand filter is impeded by accumulated solid material, the unit must be backwashed. The need for backwashing is indicated by a pressure gauge on the filter. Backwashing frequency is dependent, generally, upon the solids loading from fish in the rearing tank, character and size of the sand filter media and the efficiency of primary clarification. In fact, the major function of primary clarification is to reduce the load on the sand filter and backwash frequency.

In relative terms, sand filtration is an expensive process. It is estimated that over half the energy consumed in the perch aquaculture system is electricity to run the sand filters. Furthermore, each backwash involves the discharge of 75-100 gallons of tempered water. This constitutes a significant waste in fuel to heat water.

Some possible alternatives to pressure sand filtration include improved primary clarification, gravity sand filtration, micro screening and polyester cartridge filters.

A gravity sand filter would have to be 17-20 feet high in order to develop sufficient head for filtration rates competitive with pressure sand filtration but it is estimated that the energy to lift the water this distance would only be about one-fifth of that required for pressure sand filtration.

Cartridge filters also have a much smaller energy demand than pressure sand filters and they need not be backwashed in situ. When the cartridge becomes clogged, it can be cleaned by hosing it down with a gentle stream of unheated water.

Neither of these filters has been evaluated for applicability in water reuse aquaculture.

Biological Filtration

The final step in water treatment is ammonia conversion. Ammonia is a form of nitrogen produced by the fish and wasted feed. If allowed to accumulate in the rearing water, it will retard fish growth and eventually lead to mortality.

Ammonia can be removed by air stripping, exchange resin columns or biological filtration. Nearly all water reuse aquaculture facilities employ biological filtration as a means of ammonia conversion or removal.

In biological filtration, the clarified water flows over a media on which is grown a selective colony of bacteria. The desired bacteria are called autotrophs and are made up of two genera, nitrosomonas and nitrobacter, that utilize the nitrogenous waste of the fish for their nutrition and convert ammonia to nitrate in a process called nitrification.

$$\underset{\text{ammonia}}{2\,NH_3} + \underset{\text{oxygen}}{3.5\,O_2} \xrightarrow{\text{nitrosomonas}} \underset{\text{nitrite}}{2\,NO_2^-} + \underset{\text{water}}{3\,H_2O} \tag{1}$$

$$2\,NO_2^- + O_2 \xrightarrow{\text{nitrobacter}} \underset{\text{nitrate}}{2\,NO_3^-} \tag{2}$$

The final product of nitrification is nitrate. This is a relatively nontoxic form of nitrogen and can be allowed to accumulate to concentrations on the order of 100 ppm in the aquaculture system. The major purpose of fresh water addition is to keep the nitrate ion level in this range by dilution with new water.

Biological filter media is usually rigid and nonporous and may take the form of crushed stone, oyster shells, plastic rings or self-supporting plastic modules. Media is evaluated in terms of price versus specific surface area, weight and void space ratio. For instance, crushed stone is inexpensive but it is very heavy requiring substantial support, whereas plastic rings are much lighter, may have a higher specific surface area and void ratio but cost about seven times more than the same volume of stone. The biological filter is sized according to the specific surface area of the media because this is the area available for bacterial growth. Also, the volume of water that can be applied to the filter is partially determined by the void space ratio, so these parameters have a significant bearing on the sizing of biological filters. Filter sizing criteria will be presented in a later section.

Two types of biological filters are in use at the Aquaculture Demonstration Unit, trickling filters and upflow, or submerged, filters. The trickling filter appears to be the most useful for perch aquaculture (Quigley and Calbert, 1976). See figure 4.

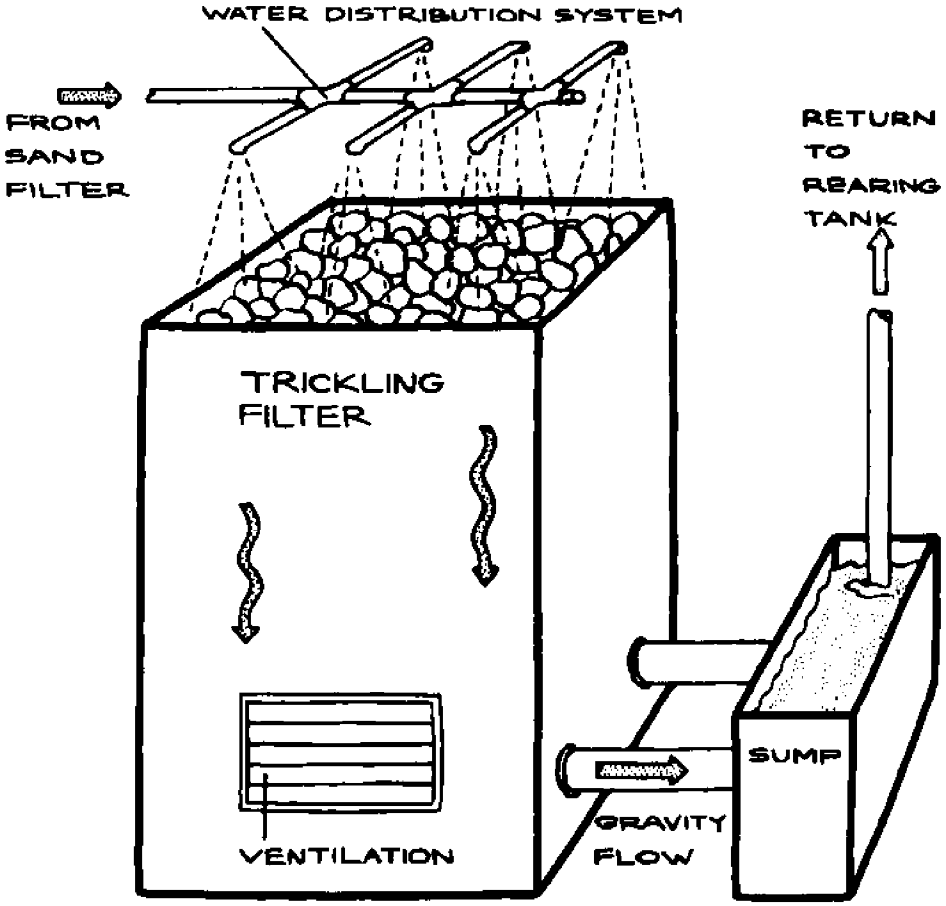


FIGURE 4 TRICKLING FILTER

In the trickling filter, effluent water from the sand filter is distributed evenly over the surface of the filter media with fixed nozzles or a rotating sprayer. It then trickles over the surface of the media, coming into contact with the bacterial colonies and collecting in a sump, finally, from where it returns to the production tank. This completes the water reuse treatment cycle.

Water enters the upflow filter from the bottom, floods up through the filter media and spills back into the production tank. See figure 5.

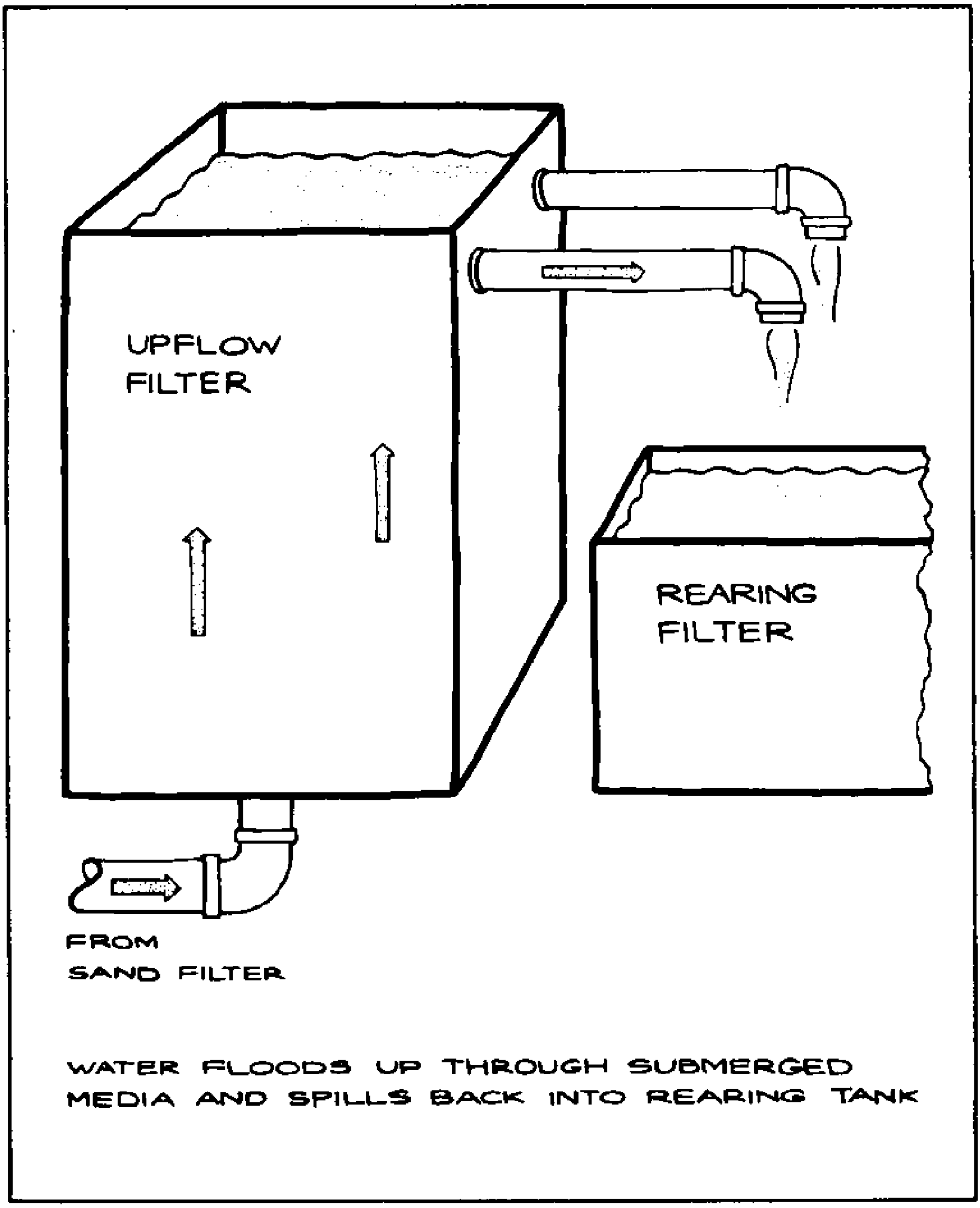


FIGURE 5 UPFLOW FILTER

In the upflow filter, the media is continuously submerged. Note from equations (1) and (2) that oxygen is required for nitrification. Biological filters must be adequately ventilated to allow free circulation of air for their proper functioning.

Nitrification

Temperature and ammonia concentration contribute to the rate at which ammonia is converted to nitrate. The ammonia production rate can be calculated in several ways as shown in the following equations (Kramer, Chin & Mayo, 1972) (Meade, 1974):

$$N_a = R_F \times \text{Biomass} \times N_L \times (1\text{-}N_u) \times N_E \qquad (3)$$

where N_a = lb of ammonia produced per day
Biomass = lb of fish
N_L = percent nitrogen in feed
N_u = protein utilization
N_E = nitrogen excreted as ammonia
R_F = feeding rate

example: 100 lbs of fish are fed 3% of their body weight per day. The feed contains 5.44% nitrogen. Protein utilization is 40% and 90% of the nitrogen is excreted as ammonia. What is the daily production of ammonia?

$N_a = 0.03 \times 100 \text{ lb} \times 0.0544 \times 0.6 \times 0.9$
$= 0.09$ lb ammonia/100 lb fish/day

$$N_a = 0.0157 + 0.0455\ 0c \qquad (4)$$

where 0c = lb of oxygen consumed per 100 lb of fish per day

and

$$0c = K \times T^n \times W^m$$

where K = species dependent constant*
T = degrees Fahrenheit
n = constant*
m = constant*
W = weight of individual fish

*These constants are for trout. Perch information not available.

example: What is the ammonia production per day of 100 lbs of fish at 70°F and an individual body weight of 0.3 lb?

$$
\begin{aligned}
N_a &= 0.0157 + 0.0455\,(3.05 \times 10^{-4} \times 70^{1.855} \times 0.3^{-0.138}) \\
&= 0.0157 + 0.0455\,(3.05 \times 10^{-4} \times 0.2646 \times 1.18) \\
&= 0.06 \text{ lb ammonia/100 lb of fish/day}
\end{aligned}
$$

$$\mathbf{N_a = 0.0289\ F} \qquad (6)$$

where F = feeding rate

example: How much ammonia is produced by 100 lbs of fish in a day if the feeding rate is 3% per day?

$$
\begin{aligned}
N_a &= (0.0289)\,(3) \\
&= 0.09 \text{ lb ammonia/100 lb of fish/day}
\end{aligned}
$$

Meade has determined that nitrification rates of 1.56×10^{-4} lb of ammonia per square foot of filter media area can be obtained at 57°F (Meade, 1974). Kramer, Chin & Mayo report rates as high as 2.0×10^{-4} lb/square foot at temperatures between 50°F and 58°F (Kramer, Chin & Mayo, 1972). Using this information, the filter surface area required for a given biomass of fish can be determined by the following equation:

$$\mathbf{F_A = \frac{N_p}{N_o}} \qquad (7)$$

where F_A = surface area required in square feet
N_p = lb ammonia produced per unit biomass per day
N_o = ammonia oxidized per square foot per day

example: What is the biofilter media surface area required for 100 lbs of fish? Assume an ammonia production rate of 0.09 lb/100 lb of fish/day and an oxidation rate of 1.56×10^{-4} of ammonia/square foot per day.

$$
\begin{aligned}
FA &= \frac{N_p}{N_o} \\
&= \frac{0.09}{1.56 \times 10^{-4}} \\
&= 579 \text{ square feet per 100 lb of fish}
\end{aligned}
$$

This basic calculation applies for either upflow or trickling filter media although the specific conversion values will differ. The size of the biological filter depends upon the specific surface area of the filter media selected. The following table gives typical specific surface area values for some common media types.

	1"-3" stone	**3½" plastic rings**	**rigid plastic module**
Specific surface area, ft^2/ft^3	19	27-31	27
Void ratio	.46	.95	.97

A full scale perch rearing tank might hold about 4,000 gallons of water. When at capacity, such a tank would be expected to hold 2,000 pounds of perch (UW Sea Grant, 1975). The specific surface area of biological filter media for this tank can be calculated from the results obtained above.

$$F_{Au} = \frac{\text{unit biomass}}{100} \times F_A$$

$$= \frac{2000 \text{ lb}}{100 \text{ lb}} \times 579 \text{ square feet}$$

$$= 11{,}580 \text{ square feet}$$

From the above table, we can determine that 609 cubic feet of stone, 374 cubic feet of 3½" rings or 429 cubic feet of rigid media are required to convert the ammonia produced by 2,000 pounds of fish.

The hydraulic load or filter flow rate must also be considered when sizing the biological filter. It is estimated that a rearing tank detention time of 30 minutes will have to be maintained in order to control ammonia production at peak fish loading. The 4,000 gallon tank must have a 133 gpm flow rate to obtain this detention time. This is the hydraulic load on the biological filter. The cross sectional area of the biological filter is determined by the drainage capacity of the media selected and this is related to the void ratio. The following series of equations can be used to calculate the dimensions of the biological filter.

example: Calculate the required dimensions of a submerged biofilter sized for a 4,000 gallon perch rearing tank using 3½" plastic ring media and operated at 21° Centigrade.

$$\mathbf{tm} = \frac{\mathbf{Et}}{\mathbf{9.8\ Tc - 21.7}} \qquad (9)$$

where tm = filter media retention time
Tc = temperature, degrees C
Et = ammonia removal efficiency, given at 55%

$$= \frac{55}{9.8 \times 21 - 21.7}$$

= 0.3 hours

$$\mathbf{t'm} = \frac{\mathbf{tm}}{\mathbf{E}} \qquad (10)$$

where t'm = calculated media retention time
E = void ratio of media = .95 for 3½" plastic rings

$$= \frac{0.3}{0.95}$$

= 0.316 hours

$$\mathbf{V_m = Q \times t'm} \qquad (11)$$

where V_m = volume of media required
Q = flow rate in cubic feet/hour

$$= 133 \text{ gpm} \times \frac{60 \text{ min/hr}}{7.5 \text{ gal/ft}^3} \times 0.316 \text{ hr}$$

= 336 cubic feet

$$\mathbf{A_L} = \frac{\mathbf{N_a}}{\mathbf{Vm \times Am}} \qquad (12)$$

where A_L = lbs of ammonia produced per day by 2,000 pounds of fish
N_a = ammonia loading rate
Am = specific surface area of media = 27 ft^2/ft^3 for 3½" rings

$$= \frac{1.8 \text{ lb/ammonia/day}}{336 \text{ ft}^3 \times 27 \text{ ft}^2/\text{ft}^3}$$

= 1.98×10^{-4} lb/square foot/day

This is consistent with Meade's estimate of 1.56×10^{-4} lb/ft^2/day for a lower temperature.

$$Af = \frac{Q}{H_L} \quad (13)$$

where Af = cross sectional area of filter
H_L = media drainage capacity, given at 2.5 gpm/ft^2
Q = filter flow in gpm

$$= \frac{133 \text{ gpm}}{2.5 \text{ gpm/ft}^2}$$

= 53 ft^2 cross-sectional to flow

$$tf = 1.6\ tm \quad (14)$$

where tf = filter retention time

= 1.6 X 0.3

= 0.48 hours

The purpose of this calculation is to provide the filter with 60% more detention capacity than that provided by the media to allow adequate contact of the water with the filter biota (Kramer, Chin & Mayo, 1972).

$$Vf = Q \times tf \quad (15)$$

where Vf = volume of filter
Q = flow rate in cubic feet/hour

$$= 133 \text{ gpm} \times \frac{60 \text{ min/hr}}{7.5 \text{ gal/ft}^3} \times 0.48 \text{ hour}$$

= 511 cubic feet

$$Df = \frac{Vf}{Af} \quad (16)$$

where Df = depth of filter

$$= \frac{511 \text{ ft}^3}{53 \text{ ft}^2}$$

= 9.64 feet

$$Dm = \frac{Vm}{Af} \qquad (17)$$

where Dm = depth of filter media

$$= \frac{336\ ft^3}{53\ ft^2}$$

$$= 6.34\ feet$$

The 4,000 gallon perch rearing tank, when at capacity with 2,000 pounds of fish, would require a biofilter with a cross-sectional area of 53 square feet and a depth of 9.64 feet. The depth of the media within the filter would be 6.34 feet. The filter contains 3.3 feet of open area so that the water can be detained long enough to provide nitrification at the specified efficiency of 55%. In addition to the ammonia conversion capacity of microbes on the biofilter surface, other surfaces such as the settler and the rearing tank walls will contribute to nitrification and this is not estimated.

example: Calculate the dimensions of a submerged biofilter sized for a 4,000 gallon perch rearing tank if 1"-3" stone is used as the biofilter media.

$$t'm = \frac{tm}{E} \qquad \text{(equation 10)}$$

where E = .46 which is the void ratio for 1"-3" stone

$$= \frac{0.3}{0.46}$$

$$= 0.65\ hour$$

$$Vm = Q \times t'm \qquad \text{(equation 11)}$$

$$= 133\ gpm \times \frac{60\ min/hour}{7.5\ gal/ft^3} \times .65$$

$$= 592\ ft^3$$

Note that this value for volume of filter media required is greater than Vf calculated in equation (15) of the previous example. This shows that in the case of stone media, sufficient detention time for the biofilter is provided by the media alone so Vf = Vm.

$$A_L = \frac{N_a}{Vm \times Am} \qquad \text{(equation 12)}$$

where Am = 19 ft^2/ft^3 which is the specific surface area for stone

$$= \frac{1.8}{592 \times 19}$$

$$= 1.34 \times 10^{-4} \ lb/ft^2/day$$

Note that the ammonia loading on stone media is slightly less than for plastic ring media. This is because the lower void ratio for stone makes hydraulic capacities lower for stone media.

$$Af = \frac{Q}{H_L} \qquad \text{(equation 13)}$$

where H_L = 1.2 gpm/ft^2 which is the estimated drainage capacity for stone

$$= \frac{133 \text{ gpm}}{1.2 \text{ gpm}/ft^2}$$

$$= 111 \ ft^2$$

$$Df = \frac{Vf}{Af} \qquad \text{(equation 16)}$$

$$= \frac{592 \ ft^3}{111 \ ft^2}$$

$$= 5.3 \text{ feet}$$

The depth of the filter is equal to the depth of the media.

The biofilter sized to a 4,000 gallon perch growing tank has a cross-sectional area of 111 ft^2 and a height of 5.3 feet if stone is selected as the biofilter media.

Note that the volume of media calculated in equation (12) is slightly lower than that computed from Meade's estimated nitrification rate of 1.56 X 10^{-4} lb ammonia/square foot/day. This is explained by the higher efficiency of nitrification at the temperature that perch are grown here. Equation (10) relates growing temperature to nitrification efficiency. Meade's data were taken from a system raising salmonids grown at a lower temperature of 57°F or less.

The amount of media required in a trickling filter can be determined by a similar approach. Detention time on the media is very short and may be increased effectively by providing a partial recycle of treated water.

In designing trickling filters, media should be selected in terms of specific surface and void fraction. Provision must be made for ventilation. The availability of oxygen is as important as that of water to the proper functioning of the filter. The design of a pilot scale trickling filter using limestone media having adequate ventilation was described in an earlier paper (Quigley and Calbert, 1976). Ventilation ducts may be combined with the underdrain layout or installed on the filter housing.

Design hydraulic loading is a function of the media characteristics and void ratio, influent properties, treatment requirements and rate of sludge accumulation. In the interest of keeping filter size down, aquaculture systems generally have used super rate filters with basic loadings in the range of 0.5 to 1.0 gpm/ft^2 to assure a minimum wetting rate throughout a synthetic media tower. Experience to date with relatively low concentrations of metabolite ammonia indicate that a 50 percent recycle ratio is desirable on an eight foot deep filter. These rates should produce 95 percent conversion of the ammonia with very low residual nitrite. The actual recycle ratio, metabolite concentration, stage of filter development, media depth and temperature affect the relative rate of ammonia removal and nitrite production and these should be monitored.

The hydraulic rate should be high enough to promote sloughing of solids as these accumulate to assure maximum activity of surface colonies and to avoid clogging. Note, however, that design hydraulic rates for trickling filters are generally lower than for upflow filters. Hydraulic loads must not be so high as to promote washing off of healthy bacterial colonies from the media surface as this would reduce nitrification efficiency. The following example illustrates trickling filter design.

Given a flow requirement of 133 gpm and a basic hydraulic loading rate of 1.0 gpm/ft^2, the surface area to flow would be,

$$Af = \frac{Q}{H_L} \qquad \text{(equation 13)}$$

$$= \frac{133\ \text{gpm}}{1\ \text{gpm/ft}^2}$$

$$= 133\ \text{ft}^2$$

If the filter is made eight feet deep and filled with a media having a specific surface area of 26 ft^2/ft^3, the surface area available for nitrification would be,

$$(133\ \text{ft}^2)\ (8\ \text{ft})\ (27\ \text{ft}^2/\text{ft}^3)$$

or,

$$28{,}728\ \text{ft}^2$$

Assuming 95 percent conversion of the ammonia and peak ammonia production at 1.8 lbs/day, the conversion rate becomes,

$$A_L = \frac{\textbf{Na}}{\textbf{internal surface area}} \times \textbf{Efficiency} \qquad \textbf{(equation 12)}$$

$$= \frac{1.8 \text{ lb/day}}{28{,}728 \text{ ft}^2} \times 0.95$$

$$= 0.595 \times 10^{-4} \text{ lbs ammonia/ft}^2\text{/day}$$

This result is well below expected ammonia conversion rates which are generally comparable to submerged filters and may be much higher (Quigley and Calbert, 1976). This may indicate that the trickling filter for the above example could be made considerably shorter than eight feet and still efficiently convert the expected peak ammonia loading of 1.8 lb per day. Trickling filters probably can be considered more efficient than submerged filters because they are well ventilated, providing ample oxygen for nitrification. Submerged filters, on the other hand, must use oxygen dissolved in the water for nitrification. It is conceivable that for submerged filters, oxygen concentration could limit the nitrification rate.

Biological filters are operated preferentially for purposes of nitrification and must be protected from high carbonaceous BOD loadings. Experience with one manufacturer's feeds has indicated that most BOD in the system is present as suspended matter. Therefore, it is important to control suspended solids and to remove them before dissolution. Plain sedimentation may suffice (Kramer, Chin & Mayo, 1972) although sludge withdrawal should be continuous. Sand filters have been used here with success and lower cost alternatives are being studied. A combination of these units probably is optimal. While not verified under a range of conditions, BOD loadings should probably be less than 10 lbs/1000 ft^3 of media per day at 70°F for the operating conditions noted above.

BOD loading can be estimated from the following equation:

$$\textbf{BOD loading} = \textbf{0.6 F} \qquad \textbf{(equation 17)}$$

where BOD loading = lbs BOD produced/100 lbs fish per day
F = feeding rate

example: 2,000 pounds of fish are fed 3% of their body weight per day. The sand filter and clarifier are designed to remove 80% of the BOD. What is the BOD loading on the biofilter if it contains 1064 ft^3 of media?

$$\text{BOD loading} = 0.6 \text{ F} \times \frac{2{,}000 \text{ lbs}}{100 \text{ lbs}}$$

$$= (0.6)\ (3)\ (20)$$

$$= 36 \text{ lbs BOD per } 2{,}000 \text{ lbs fish per day}$$

$$\frac{36\ \text{lbs} \times 0.2}{1064\ \text{ft}^3} = \frac{x}{1000\ \text{ft}^3}$$

where x = BOD loading per 1000 ft^2 of media per day

x = 6.8 lbs BOD per 1000 ft^2 of media per day

This should be acceptable for operation in accord with experience here to date.

Sizing Tube Settler & Sand Filter

Tube settler media is sold as a plastic module. The dimensions are usually 10′ long X 2½′ wide X 1½′ deep. It is estimated that sufficient primary clarification can be obtained with a flow rate through the tube settler equal to 2 gpm per square foot of top surface area, or 50 gpm per module. If a tube settler is sized for a 4,000 gallon rearing tank, at least 66.5 square feet of tube settler media would be required to accommodate the 133 gpm flow through. A convenient way to build a tube settler of this size would be to use three 10 foot modules. The unit, then, would have a top surface area of 10 feet X 7.5 feet or 75 square feet. The depth of the unit below the tube settler media should be about the same as the depth of the rearing tank or 4 feet. With 2 feet added to accommodate the media and freeboard, the tube settler unit is 6 feet deep.

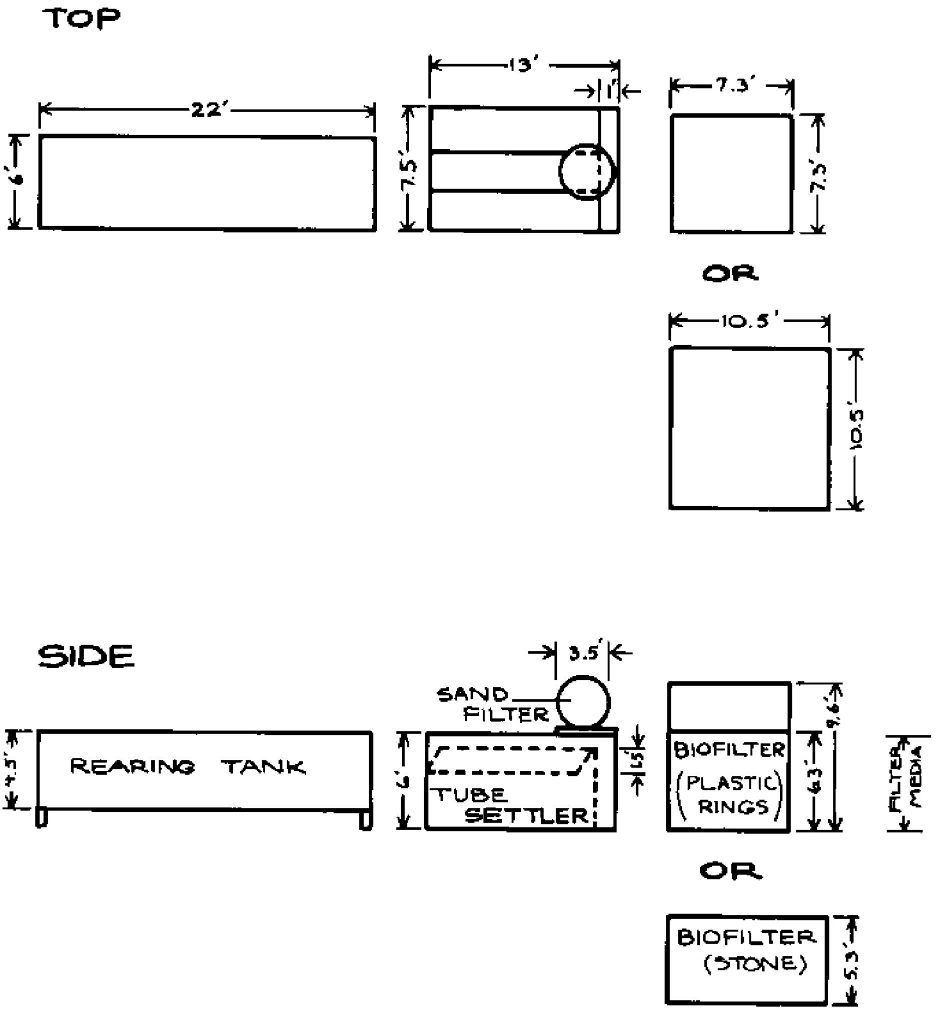
Sand filters can be sized according to the flow rates provided by the manufacturer. However, this rating is a maximum flow that is only attained immediately following backwash. Actual design flow rates must be somewhat less than this. Effective sizes in the range of 0.4 mm to 2.0 mm have been used in aquaculture systems here. A uniformity coefficient of 3.5 has proven satisfactory. Using a standard mix of sand furnished for use with a swimming pool unit, sand filters for aquaculture can be sized to within 2/3 of this recommended flow capacity. The following table gives sizing information for some standard sand filters.

filter size diameter, inches	HP	GPM flow maximum	recommended working flow for aquaculture
24	¾	47	31
24	1	63	42
24	1½	78	52
30	1½	74	49
30	2	98	65
34	2	94	63
34	3	126	84
42	3	148	99
42	5	196	131

It is expected that adequate filtration will be possible using a coarser sand media than the standard mix. This would reduce the size of the sand filter required.

Our 4,000 gallon tank would require a 42 inch sand filter with a 5HP pump, using a standard mix of sand furnished for use with a swimming pool. Figure 6 shows a 4,000 gallon rearing tank and properly sized water reuse system.

Note the size differences in the biofilters depending upon the type of media selected.



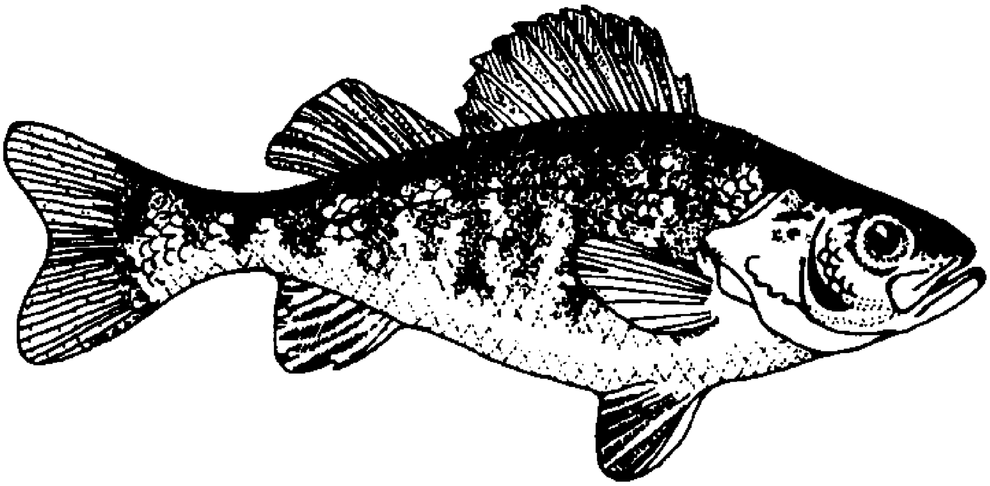
THIS PERCH AQUACULTURE SYSTEM IS SCALED TO A 4,000 GALLON REARING TANK. EITHER BIOFILTER CAN BE USED.

FIGURE 6 PERCH AQUACULTURE SYSTEM SCALED TO 4000 GALLON REARING TANK. NOTE SIZE COMPARISONS OF BIOFILTERS USING PLASTIC RING AND STONE MEDIA.

The sizing criteria presented in this paper are based on fairly conservative upper limits for ammonia and nitrite concentrations in the production water. Research planning is presently in progress to determine the chronic toxicities of perch to these compounds and this information will provide a more accurate basis for filter sizing criteria.

Meade's recent work on nitrite and ammonia toxicities indicates that through water chemistry manipulation, higher levels of these metabolites can be tolerated by the fish than was previously suspected. Since nitrification efficiency is partially determined by influent nitrite and ammonia concentrations, biological filters could be made smaller if higher concentrations of these compounds could be tolerated.

The possible impact of this research is that more floor space could be devoted to rearing tanks and less to the biological filters. Less water would have to be recirculated and biofilter media costs would be reduced.



QUESTIONS AND ANSWERS FROM TECHNOLOGY OF PERCH AQUACULTURE

October 25, 1977

Q. **What flow rate are you running through these filters?**
Soderberg: We adjust our flow rate to maintain a detention time of around 30 minutes in the rearing tank. A 2,000 gallon tank would have a flow of about 67 gallons per minute so that the water would be detained for 30 minutes.

Q: **Have you ever tried a diatomaceous earth filter?**
Quigley: It has been proposed and it would be an alternative but we just haven't tried it yet.

Q: **Would a gravity sand filter actually have to be 17-20 feet high or could 17-20 feet of pressure be applied to a lower unit?**
Quigley: The sand filter bed would normally be only 2-3 feet deep. It should have a relatively finer media above and coarser below, ranging from sand to gravel, perhaps. The head pressure of water required for this type of filter would be on the order of 20 feet.

Q: **When you compute the area of the trickling filter, are you taking into account the entire filter bed?**
Soderberg: In our calculation we only took into account the media itself and not the sides of the container, insides of pipes and other contributing surfaces.

Q: **What I meant was, if the entire container is filled with media, are you computing the entire area of all that media?**
Soderberg: Yes. You will see from the examples that the depth of the biofilter is determined by the amount of media needed and the required amount of media has quite a lot to do with its specific surface area.
Quigley: I might add that any surface area in the system may be useful so we regard additional surface throughout the system as kind of a bonus and a safety factor.
Soderberg: I think that the question is whether or not the whole depth of media is used for nitrification and the answer to that is yes.

Q: **What has been your experience using the Styrofoam peanuts for biofilter media?**
Soderberg: These biofilters are in use around the state and we have been monitoring the performance on some of them. We haven't raised a complete crop of fish on one of these units yet so we don't know what will happen when the fish loads on these filters increase. We also don't know the effective surface area and void fraction for this type of media. These will probably have to be determined empirically from the nitrification performance. Styrofoam looks like a promising biofilter media because it's lightweight and inexpensive but we're not in a position to recommend its use at this time.

Q: **We have a pilot plant in operation and we seem to be having a lot of success with it to this point. Our problem is getting fingerlings.**
Soderberg: We are going to address that problem in December (1977) with a conference on fingerling production. I feel that persons going into commercial perch aquaculture will have to raise their own fingerlings because the cost of a purchased fingerling is too high in relation to the value of the finished fish. This is because perch are marketed at a small size, requiring more fingerlings per pound of fish produced than other species being cultured.

Q: **Are there any pilot plants located in Wisconsin at the present time?**
Soderberg: There are six that I know of.

Q: **Are they in operation?**
Soderberg: Yes, but most of the fish being grown privately are from this year's hatch and won't be marketed until sometime next spring. There were only a few fish marketed last year.

Q: **What was the size of these finished fish and what was their age?**
Soderberg: That I don't know. We feel that our estimate of 10 months for the growing period is accurate if you raise the fish at the temperature we specify.

Q: **Has anyone tried injecting oxygen in the water flow to assist nitrification in upflow filters?**
Soderberg: Not here but I think this has been done. You could drop an airstone in the influent pipe or perhaps aspirate air into the pipe.

Q: **Do we know if this is feasible from an economic standpoint?**
Quigley: It has been done in various wastewater treatment systems. I know Dr. Meade has done it on his aquaculture system in Rhode Island. The economics of aerating the biofilter would probably depend upon how concentrated the ammonia is and therefore how large the filter has to be. Most of our experience to date has been with trickling filters and we have a lot to learn about flooded filters.

Q: **What are the advantages of cartridge filters?**
Soderberg: We don't know yet but for one thing, they don't require backwashing. When flow is impeded through the cartridge filter, it is indicated on a pressure gauge and the cartridge is replaced. We don't know how long the cartridges will last or how many times they can be reused. I would expect that the cartridge filter would operate on a lower pressure loss than the sand filter and therefore be more energy efficient. We don't know yet if this is true.

Q: **What do you do with the effluent from the sand filter backwash?**
Soderberg: It is discharged.

Q: **Where will the DNR allow this waste to be discharged?**
Soderberg: We have studied that problem closely and the present DNR discharge regulations are that any aquaculture system producing over 20,000 pounds of fish per year needs a discharge permit if the discharge goes into waters of the state. If the waste is disposed of on land, a discharge permit is not required.

Q: **Is the quality of the discharge such that the DNR will accept it?**
Soderberg: The DNR will monitor BOD and suspended solids. It is rather arbitrary how they determine discharge criteria; it depends upon the quality and volume of the receiving water. Obviously you can put more BOD and solids into the Wisconsin River than into a small trout stream. The best method of disposing of this waste is to irrigate with it. Then you are in the same category as a dairy farmer. You are spreading your waste on land.

Q: **I have discussed discharge regulations for aquaculture with the DNR and they are apparently looking at the EPA guidelines that give fairly specific recommendations and guidelines for levels of suspended solids, settleable solids, ammonia and pico-coliform for a warm water hatchery. The ammonia standard is a monthly mean of .09 pounds per 100 pounds of fish per day. Based on your experience at the demonstration unit, can you meet this?**
Quigley: It depends on where you choose to discharge from the system. For instance, if you take your discharge from the biofilter sump there should be no ammonia present; the nitrogenous material would already be oxidized to nitrate. From my experience with the trout hatcheries around the state, the DNR so far hasn't been too concerned with ammonia, but again, this could depend on the receiving water. If you are dumping into a valuable trout stream, they are going to be more concerned with the discharge than if you are discharging into a larger volume of receiving water. So far, they haven't measured ammonia in the discharges. The discharge criteria for aquaculture systems is rather vague right now. The EPA is making their decisions and the DNR is deciding whether they should go along with those or make the criteria even more stringent than the EPA guideline.

Q: **As a sidelight, that 20,000 pounds of fish per year limit that you mentioned is being contested in federal courts.**
Soderberg: I know it is, but that's the guideline that is presently in use. If you are producing less than 20,000 pounds of fish per year—for instance in a hatchery or fingerling operation—you would be exempt from discharge regulations. I believe that will change.

Q: **Your calculations are obviously for a full load situation where you've got a 4,000 gallon tank with 2,000 pounds of fish in it. When you start as fingerlings, do you need to run that system all the time?**
Soderberg: That is a very good question. The pumps and filters are sized to allow a 30 minute detention time for water in the rearing tank because we feel this is necessary to insure fish health at peak loading. The required turnover time of the water is estimated by measuring the rate of ammonia accumulation. Water flows through the system do not need to be as great during the growth period as they are at harvest time, but the pumps are

running at full capacity all the time. This is a major flaw in the way we're presently culturing fish.

Quigley: We are working on a paper right now which will describe a production scale facility in which we show how to allocate a given flow of water to various rearing tanks according to their fish loadings. By rotating flows among the tanks in the facility, the treatment capacity is more completely utilized and the system becomes more energy efficient.

Q: **Could you run the filter at full capacity part of the time and then store the filtered water and use it gradually for the rest of the period?**

Soderberg: I don't see how you could economically build a large enough storage container. You must always consider the floor space required. Buildings are very expensive to build and to heat. Space requirements must be minimized.

Q: **Could you put a timer on the filter?**

Soderberg: Then the biofilter media would be dry part of the time. I don't believe the filter biota could survive this type of fluctuation in their food supply.

Quigley: We could possibly put a recycle around the filter, but I think you would find the fish are much more comfortable if you are circulating water continuously through the system. It would be undesirable to be in a situation where the ammonia levels would be allowed to build up in the tank and then be pulled down by starting the pump for a short period, only to let the levels increase again. I think this would have an adverse effect on fish health.

Q: **What about the effect on the pump of having it started up and turned off again several times a day?**

Quigley: I think that it would be a very poor way to run the system.

Q: **Have you established specific ammonia tolerance levels for perch? Are they the same for young and old fish?**

Soderberg: That is a very good question and this is something that we've just begun to work on. Nitrification efficiency is determined by influent nutrient levels as well as temperature, so if we can operate at higher levels than what we have conservatively set, our biofilters could be made smaller. Dr. Meade's work in Rhode Island indicates that by manipulation of water chemistry, fish can survive much higher levels of ammonia and nitrite than was originally suspected. We are now doing the bioassays to determine what the chronic toxicities of these metabolites to perch are. This is a complicated problem because individual water chemistry can so drastically influence the toxicity of these compounds. We don't know all the reasons for this but it appears that chloride is the important element in protecting against the toxicity of nitrite.

Q: **Are you planning any work on controlling the speed of these pumps with variable speed motors or direct current variable speed?**

Soderberg: No. I believe that the most practical way to run the system would be to selectively manifold the discharge from a single pump into several tanks rather than controlling the pumping capacity of several smaller pumps.

Q: **I would like to try raising perch in a building I have in Sturgeon Bay. Is it permissible to pump the water out of the bay for fish husbandry?**
Soderberg: You would have to check with the DNR but I don't think they would allow it. A possible problem would be that fish grown in Lake Michigan water might accumulate PCBs present in the water. Although research has shown that fish take up only small amounts of PCBs from the water they're in, most of the PCBs which accumulate in their tissues come from their food sources.

Q: **What should the temperature in the building be and what should the temperature of the water be?**
Soderberg: The optimum growing temperature was determined to be 70 degrees, but it's easier to control disease if the water temperature is held at about 65 degrees. We don't know how much this five degree reduction will lengthen the growing period. I don't think you'll gain much by space heating. The warm water in the tanks should keep the building warm. In the winter it would be rather cool in the building, but the water still has to be maintained at the growing temperature you select. It's easier to transfer heat from water to air than from air to water. The building must be very well insulated for this aquaculture system to work.

Q: **Does the system get too warm in the summer?**
Soderberg: Again, it will depend upon how well insulated your building is. Last summer we had to add extra cold water to keep our system cool enough because the doors were open much of the time.

Q: **Have you investigated de-nitrification?**
Quigley: Mr. Meade, some of whose articles we've referenced, has done work on biological de-nitrification. We haven't attempted it.
Soderberg: For those who don't know what de-nitrification is, it's the process where nitrate, the final product of nitrification, is converted to atmospheric nitrogen in an anaerobic system. Theoretically, if de-nitrification is employed, a discharge is unnecessary because the purpose of adding make-up water is to dilute out the nitrate.

Q: **If water is manifolded from one biofilter back to several tanks, don't you increase the instance of disease?**
Soderberg: Yes. Disease organisms from one tank will be transferred to others. This is something we'll have to learn to live with because it just isn't economically possible to have a separate filtration system for each tank.

Q: **You talk about a 4,000 gallon tank. Is this the largest size you would use and would you increase production by going to multiple tanks of this size?**
Soderberg: We have considered the sizing of tanks quite carefully and have determined that a rearing tank shouldn't be deeper than four feet, wider than six feet or longer than 30 feet. These dimensions would limit tank size to 5,000 gallons and under. We believe that this would be the largest tank that could be easily managed adequately. A commercial fish farm would, of course, have many of these tanks.

Q: **In your system at the university do you have what we call a constant BOD loading to the system?**
Quigley: We have fluctuations in BOD and ammonia loading. During the day when we are feeding, BOD and ammonia are much higher than at night.

Q: **Is it possible to feed continuously?**
Soderberg: I don't think the fish would feed during the dark period of the day so continuous feeding would raise the conversion rate. I think the optimum feeding schedule would be gradual feeding throughout the light period of the day which is 16 hours.

Q: **Can you use the trick we use in the egg business of tempting them to eat more with artificial lighting?**
Soderberg: We do that. We maintain a 16 hour photoperiod with artificial lights. No sunlight gets into our facility.

Q: **Do you move these fish from tank to tank as they grow or harvest them from the tank they were started in as fingerlings?**
Soderberg: We leave the fish in a single tank for the whole growth period so if we expected to harvest 1,000 lbs we would stock 3,000 fish.

Q: **It appears to me with 70 degree temperature, 16 hours of light and 100 ppm nitrate you would create optimum conditions for algae growth.**
Soderberg: We don't allow photosynthetic activity to occur. The only lights in our system are incandescent.

Q: **What about fluorescent lights?**
Soderberg: Fluorescent light will allow algae growth and, besides, the fish are healthier under the dim light afforded by small incandescent bulbs.

Q: **Do you know what your ratio of food input to consumption is?**
Soderberg: If the fish aren't eating the food, we stop putting it in the tank so all the food added is consumed. We are aiming for a feed conversion of about 1.5 pounds of feed per pound of gain and this is probably obtainable in this type of system. When the fish are small, they seem to convert better than when they are larger. When the fingerlings start out, the feed conversion may be as good as 1.2 but as they grow, it increases to 2.0 or more. The average should be 1.5 or 1.6. Fish are the best feed converters of any animal grown.

Q: **What kind of feed do you use?**
Soderberg: A commercial trout diet.

Q: **Can we take Great Lakes trash fish like alewives, remove the pollutants and make fish meal from them for use in fish feeds?**
Soderberg: We have a project to explore this possibility. We don't know to what degree we can remove the PCBs through extraction of the fat and how much PCBs the perch would accumulate from the contaminated feed. I think we can catch alewives here as cheaply as menhaden or anchovies are caught elsewhere so we should be able to make cheaper feeds if we have a local supply of fish meal.

Q: Could you tell me what would be the effect of keeping the water temperature at 55 degrees?

Soderberg: They wouldn't grow. You can raise trout at 55 degrees but not perch.

Q: What is the minimum temperature if 65 degrees is optimal?

Soderberg: I don't really know with perch. I would guess that at about 50 degrees growth would stop completely.

Q: Do you need supplemental aeration?

Soderberg: Yes. The biofilter as well as the rearing tank must be aerated. We use one small agitator type aerator for each 2,000 gallons of rearing tank volume.

Quigley: We hope to do some work to find more efficient means of aeration like U tubes or aspirators.

Q: Is there potential for commercial production of grass carp in this climate?

Soderberg: The DNR won't allow the introduction of this potentially harmful fish to Wisconsin. We should not be party to its introduction under any circumstances. I think there might be a market for these fish here someday for wastewater treatment but not as a food fish.

Q: What about catfish?

Soderberg: Catfish aren't worth enough to support the water reuse system. In this type of energy intensive system you must raise a fish that is worth a lot of money, a luxury gourmet food type item like perch.

Q: What can you say about building designs?

Soderberg: Right now I would recommend the cheapest possible building that can be adequately insulated. We don't really know what that is yet. We are working on a cost analysis and the building ends up accounting for nearly half of the capital expense for a fish farm of this type.

Q: How are you heating the water and what is the cost of heating?

Soderberg: We use a household gas water heater. Since we employ such a high level of reuse, only a small amount of heated water is added each day. We estimate that for every pound of fish produced, it will cost 13¢ in fuel for heating. This amounts to about 8 percent of the cost of production.

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